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Emission reduction potential across the long-haul network

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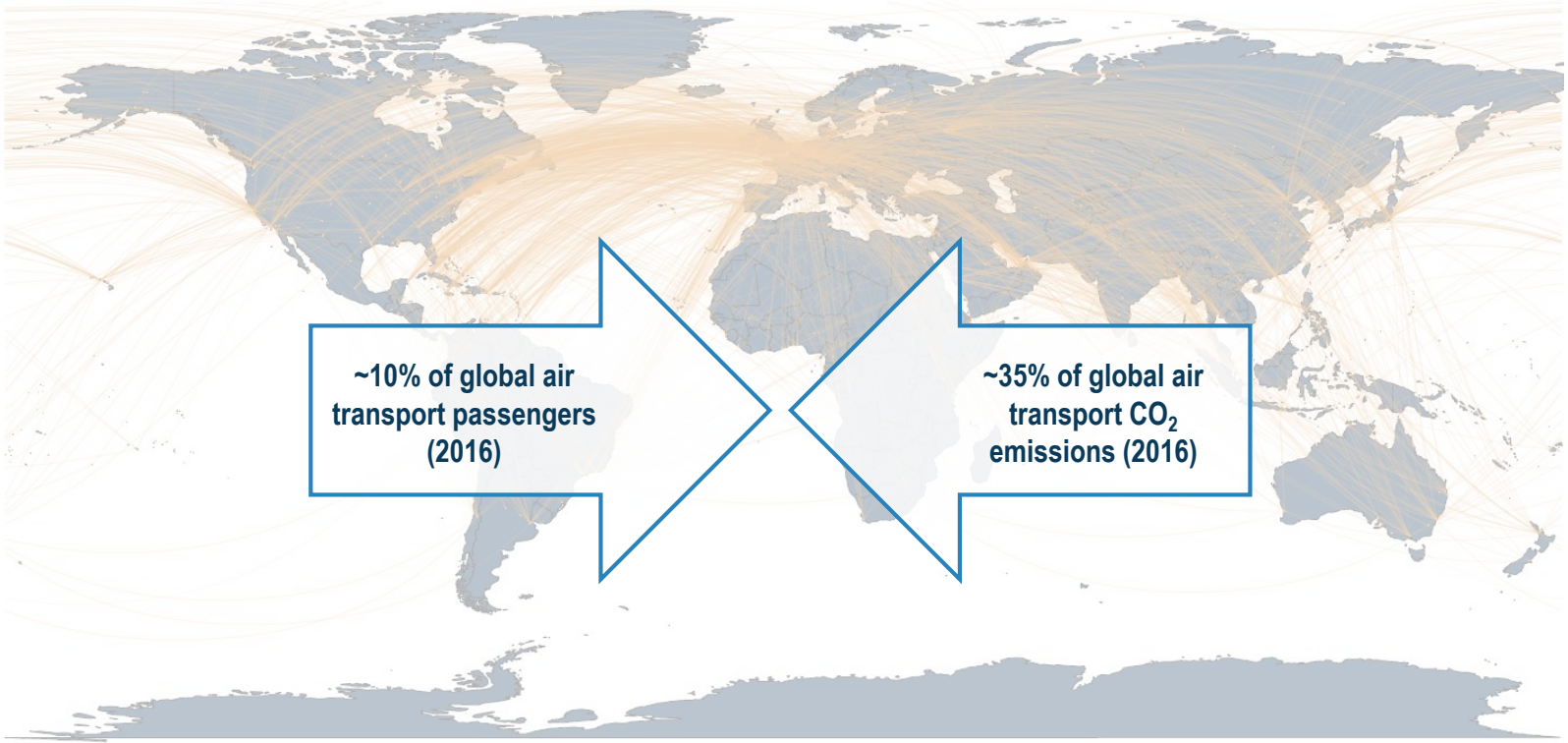
October 1, 2019

The Long-haul Air Traffic Market



Source: OAG 2016, Eurocontrol Base of Aircraft Data (BADA)

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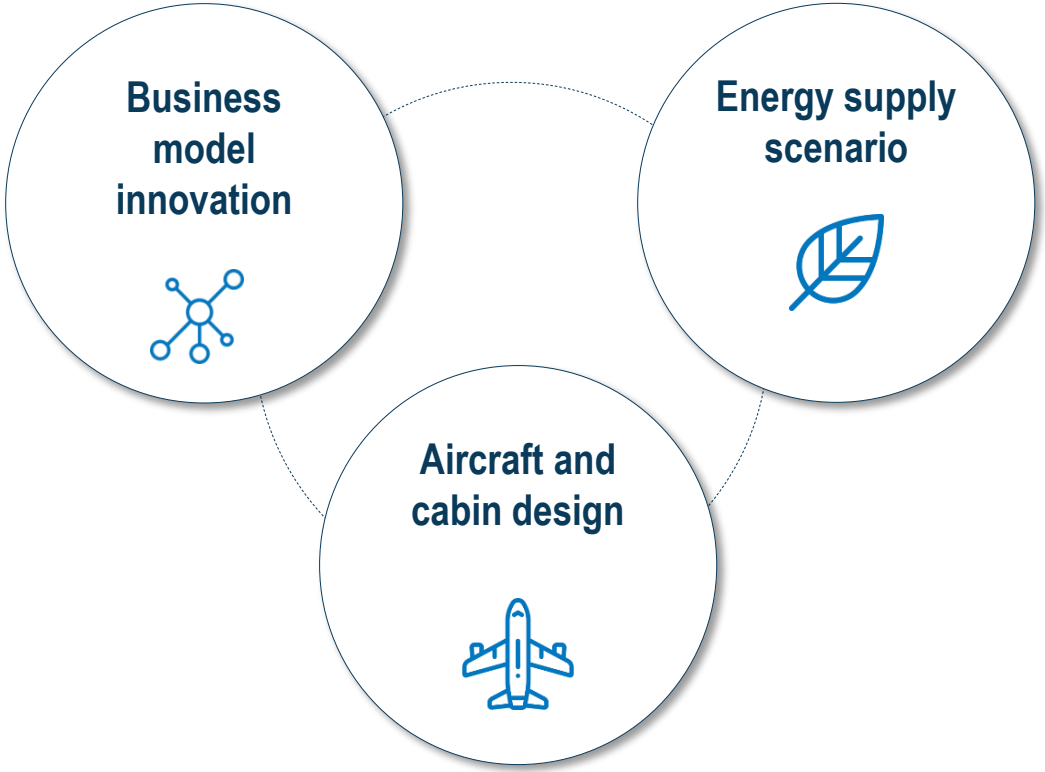
Goal of Bauhaus Luftfahrt Group Design Project 2019

The design of a

- long-haul traffic concept
- fulfilling emission reduction goals
- by incorporating measures to enhance both operational (on the air transport system level) and technical efficiency (on the aircraft level),
- keeping in mind passenger comfort and requirements.

Holistic Approach for Long-haul Network Emission Reduction



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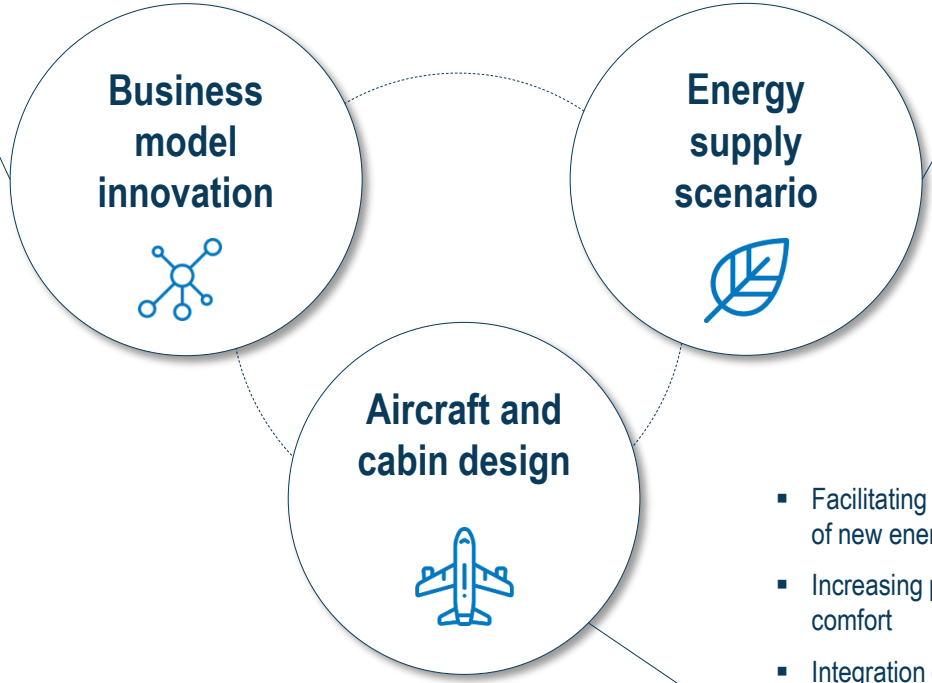
Re-thinking the Long-haul Network Structure



- Aircraft Sharing: Implementation of ShAirline business model
- Continuous connecting banks to reduce on-ground time
- Novel on-board services

- Energy supply scenario with liquid hydrogen
- Realizing benefits from scalable and cost-efficient production

- Facilitating the integration of new energy sources
- Increasing passenger comfort
- Integration of new technologies

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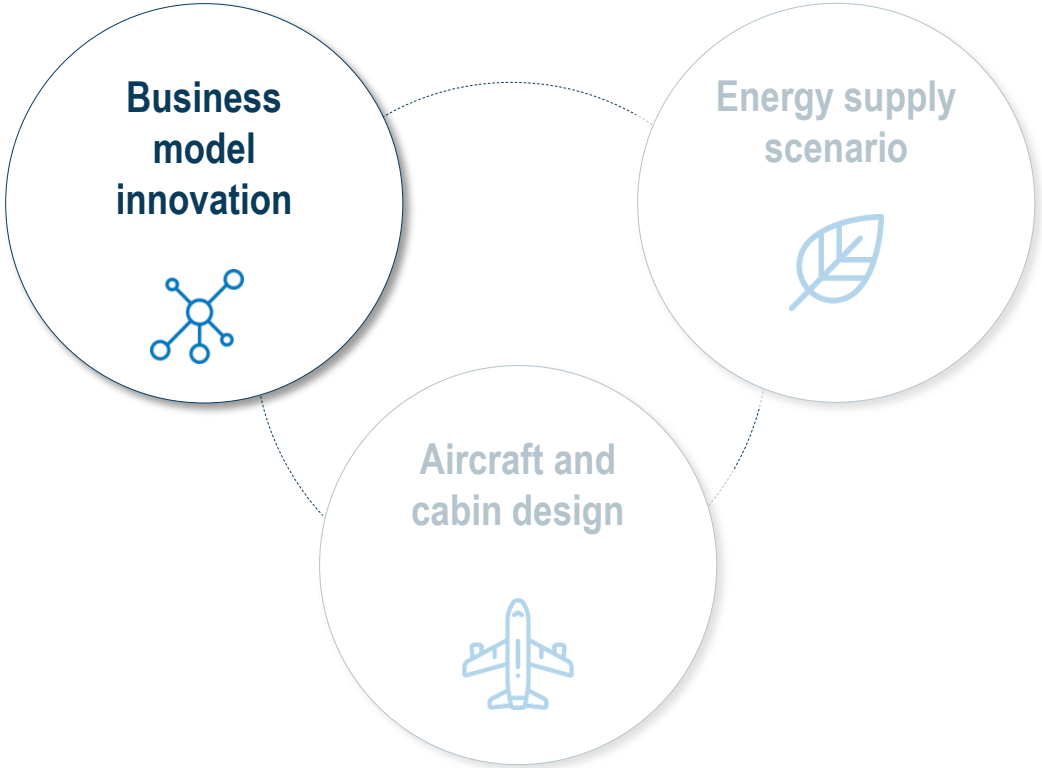

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Inefficiencies on Long-haul Network

Distribution of passengers across direct and indirect flights

Direct (38%)	Indirect (62%)
Indirect available (97%)	Direct available (37%)
Indirect cheaper (72%)	Direct cheaper (26%)

Majority of today‘s long-haul passengers travel on **indirect connections**.

Source: Sabre 2017

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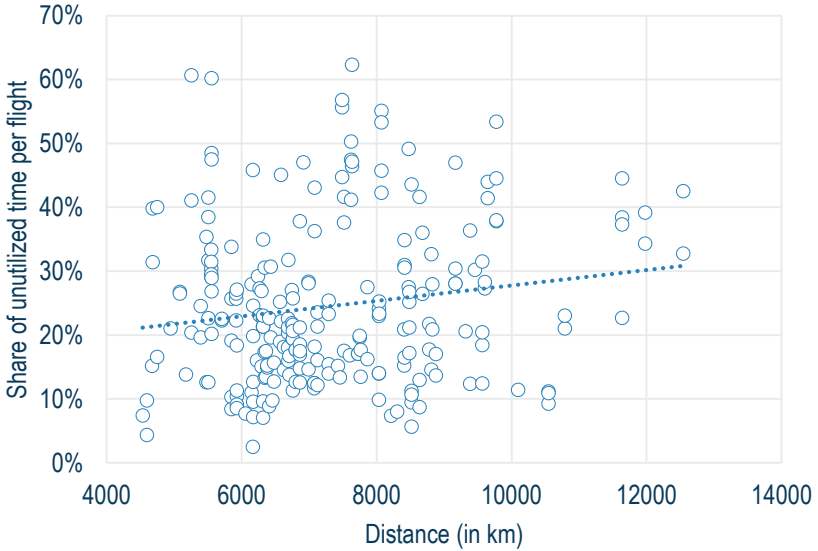
Inefficiencies on Long-haul Network



On average **~25% of unutilized on-ground time per long-haul flight** (after maintenance and turnaround)

Source: FlightRadar 24

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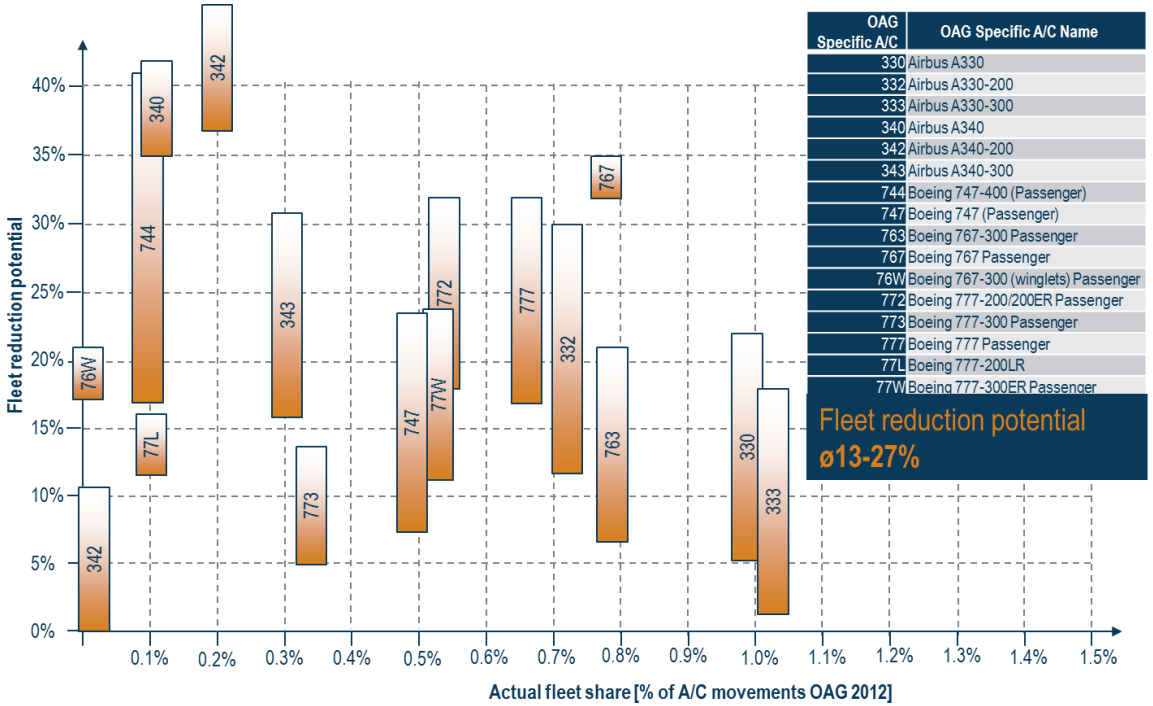
Aircraft Fleet Composition

- Aircraft sharing as enabler for a more efficient network structure
- Fleet reduction potential: ~ 13 – 27%



OAG Specific A/C	OAG Specific A/C Name
330	Airbus A330
332	Airbus A330-200
333	Airbus A330-300
340	Airbus A340
342	Airbus A340-200
343	Airbus A340-300
744	Boeing 747-400 (Passenger)
747	Boeing 747 (Passenger)
763	Boeing 767-300 Passenger
767	Boeing 767 Passenger
76W	Boeing 767-300 (winglets) Passenger
772	Boeing 777-200/200ER Passenger
773	Boeing 777-300 Passenger
777	Boeing 777 Passenger
77L	Boeing 777-200LR
77W	Boeing 777-300ER Passenger

Source: OAG 2012

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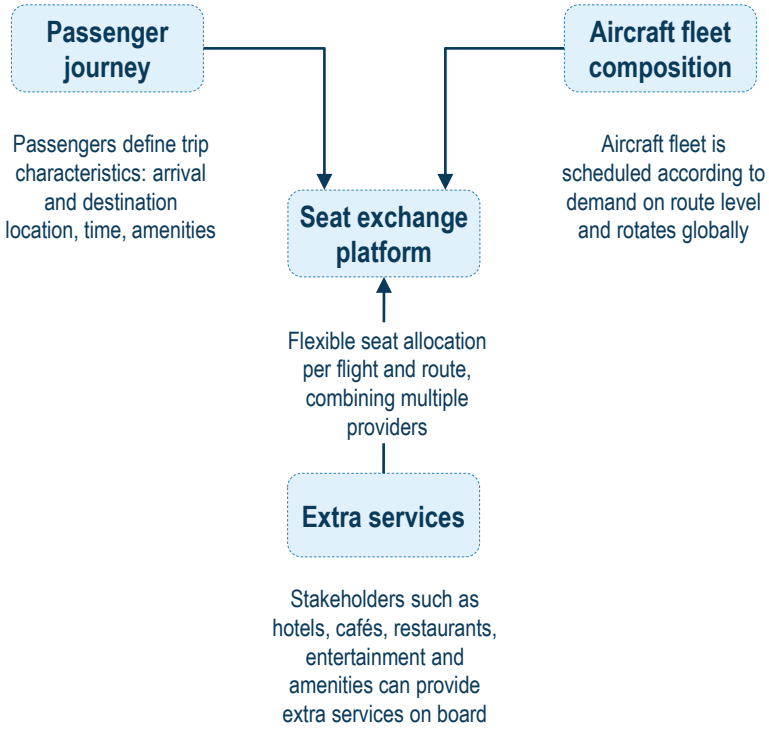
Business Model Innovation



Implementation of seat exchange platform

- Abandoning airline-aircraft ownership concept
- Renting out physical aircraft space to multiple providers “by the hour”
- Enabling flexible passenger assignment on route level
- Meeting fluctuations in demand

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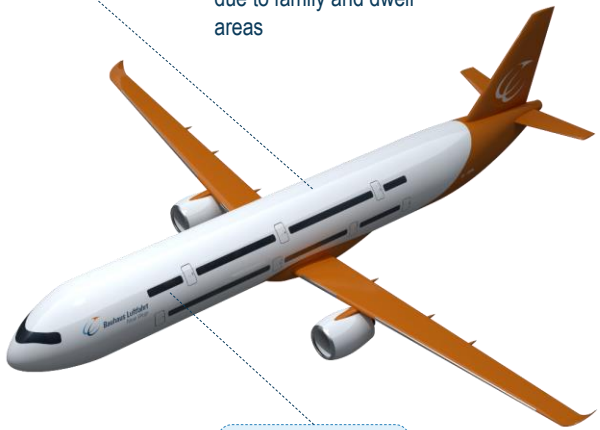
Seat Exchange Platform

Passenger journey

- 2-deck seating options with increased seat pitch
- Added value during flight due to family and dwell areas

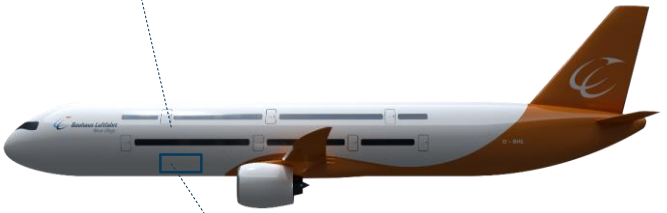


Seat exchange platform

- Lower entry barrier for new providers due to removal of airline lock-in effect
- Process optimization due to integrated data platform

Aircraft fleet composition

- Customizable white label air transport (OEM)
- Potential for more efficient standardization
- Optimization of MRO cycles and economies of scale



Extra services

- Lower deck containers providing additional passenger amenities
- Adjustment to flight duration and time of day

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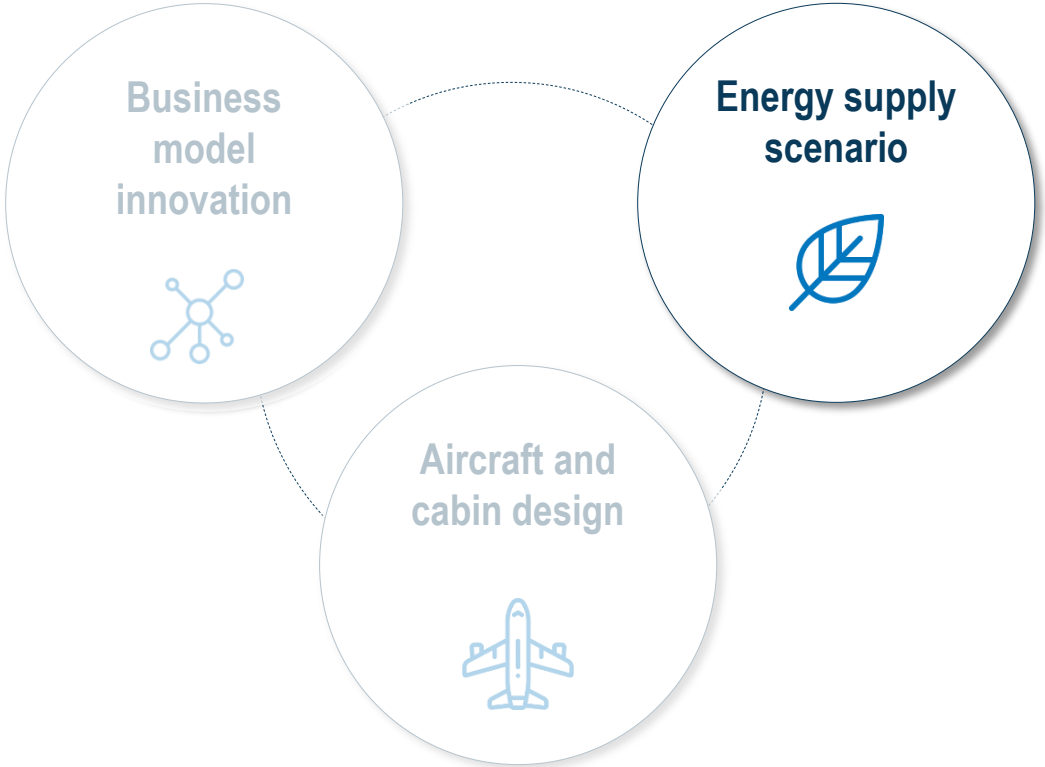

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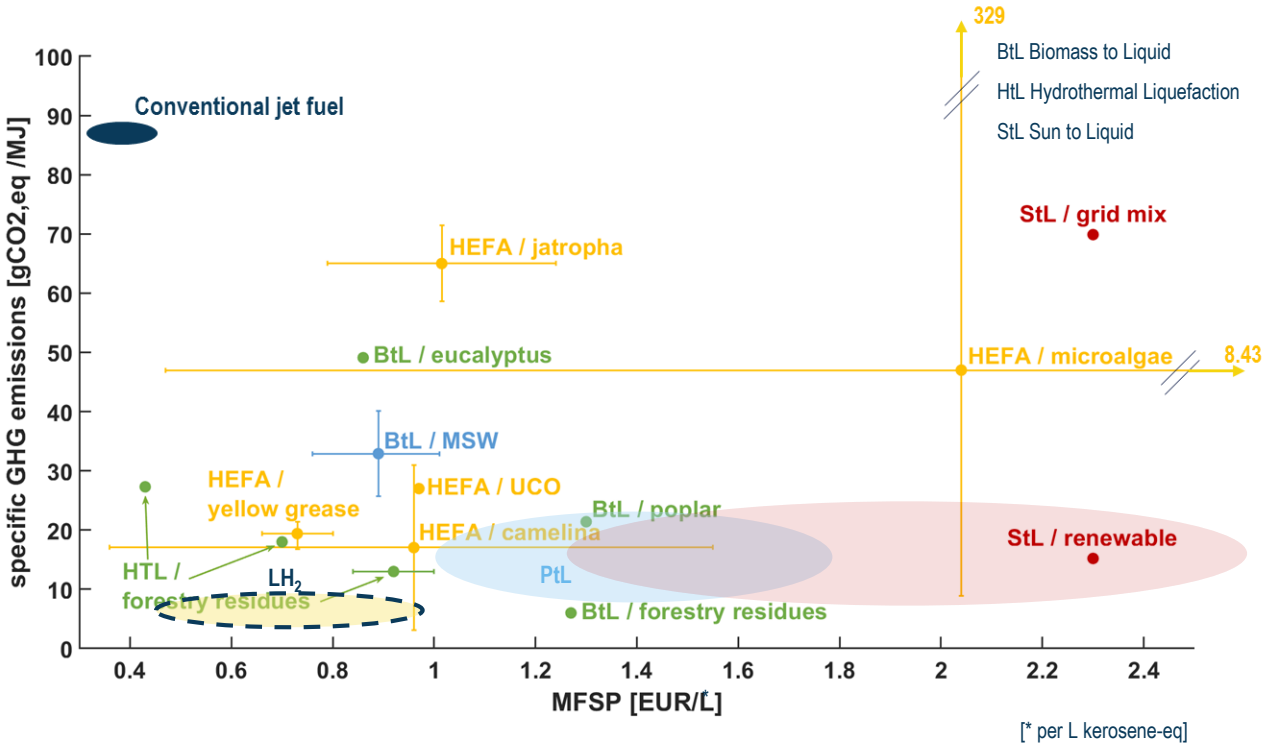
LH_2 vs. (Alternative) Fuels



BtL - Biomass to Liquid; HtL - Hydrothermal Liquefaction; StL - Sun to Liquid

Source: Results from EU FP7 Project CORE-JetFuel, continuously updated according to BHL renewable fuel literature data base.

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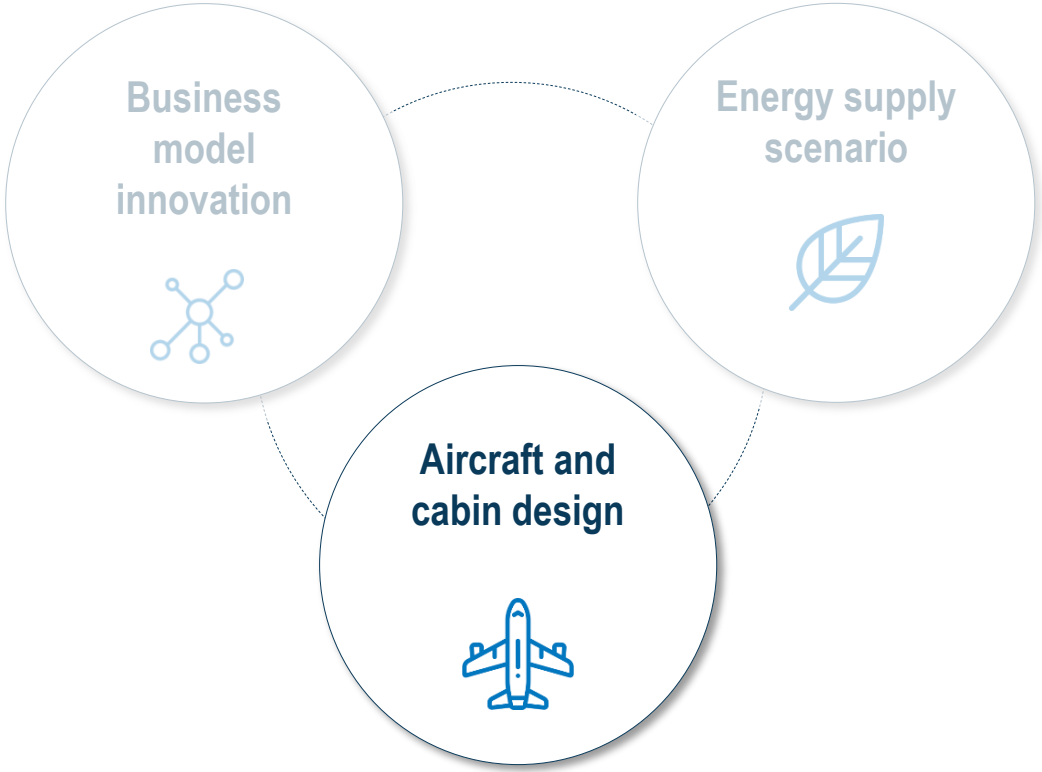

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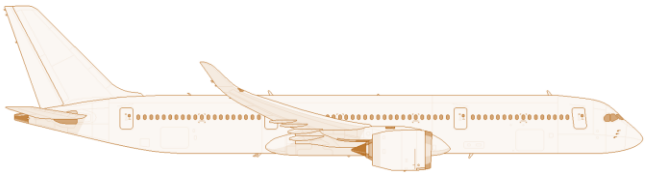
The Aircraft Platform

Existing Long Range Model

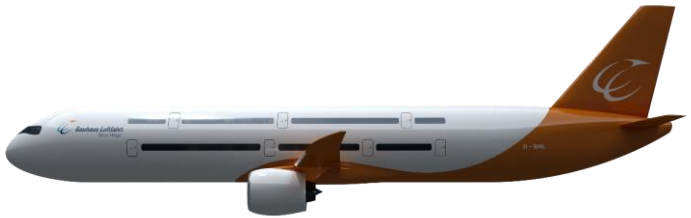


- High cruise Mach number ➔ Reduction of block times
- High overall vehicular efficiency

- Flight Mach number ↓
- LH_2 as fuel

- Increased passenger comfort
- More direct flights
- Enable onboard service models

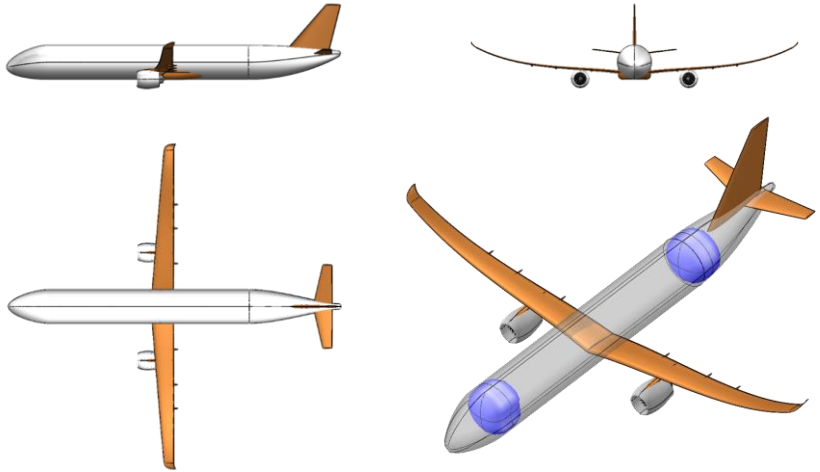
ShAirline Long Range Model



- Design cruise Mach number ~ 0.7
- Increased seat pitch + comfort/dwell areas
- LH_2 tanks (front & rear)
- Lower deck ➔ service elements

Resulting Aircraft: 3-View & Key Performance Data

	C004	Conv. Ma 0.82 AC
MTOW	196 t	264 t
Wingspan	81 m	67 m
Wing Loading	588 kg/m²	713 kg/m²
Fuel Mass Design Mission	18.6 t	72.5 t
OEW	128 t	138 t
Total Installed Tank Volume	371 m³	128 m³



Source: Troeltsch (2019)

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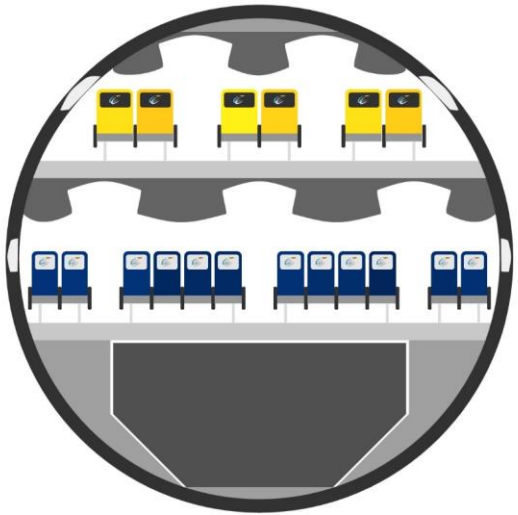
Aircraft Cabin Design

Different areas for passengers

- Meeting and working areas
- Upper deck: 6 abreast with 2 aisles, 64” seat pitch
- Main deck: 12 abreast with 3 aisles, max. 1 person to pass, 36” seat pitch (+16%*)
- Cargo Deck: swappable containers, height 2.40m, accessible via staircase



Integration of various service elements

- Hotels, restaurants, dwell areas
- Engagement of multiple service providers in renting out space

*compared to a Lufthansa A380

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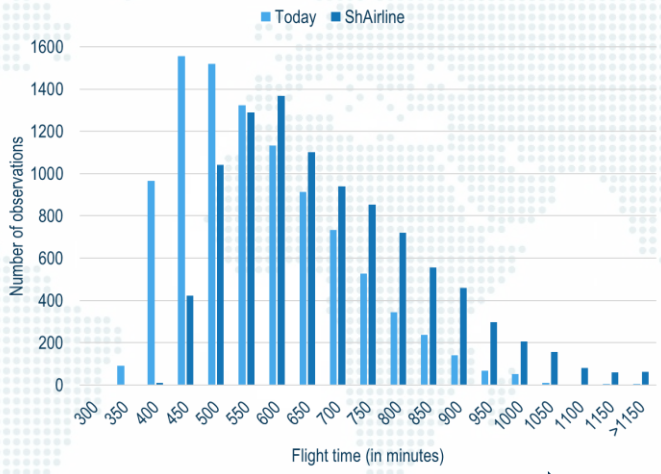
Passenger Journey

East-West-bound traffic (2016)

- Repr. Cluster: **28%** of flights on this market
- **12:12h – 15:59h** [weighted mean times]

Daytime flights



East-West-bound traffic (ShAirline)

- Repr. Cluster: **26%** of flights on this market
- **12:04h – 17:35h** [weighted mean times]

North-South-bound traffic

- Repr. Cluster: **44%** of flights on this market
- **21:43h – 06:48h** [weighted mean times]

Nighttime flights

North-South-bound traffic (ShAirline)

- Repr. Cluster: **42%** of flights on this market
- **21:49h – 08:30h** [weighted mean times]

Source: OAG 2016

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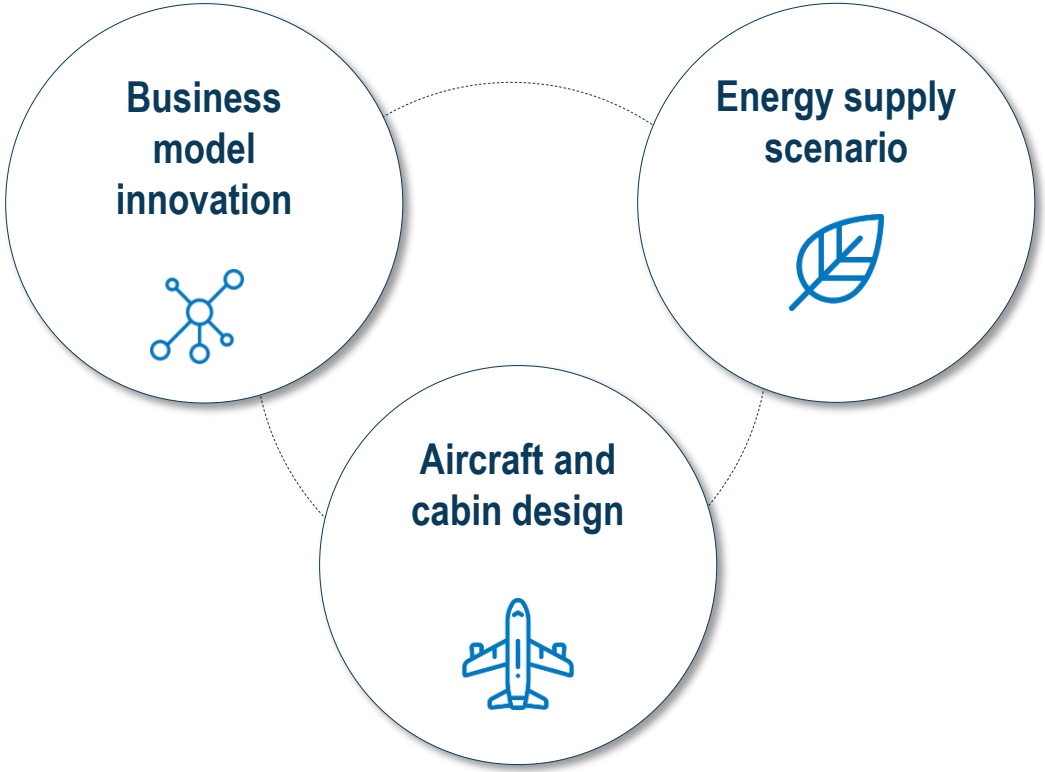
Holistic Approach for Long-haul Network Emission Reduction



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Initial Emission Reduction Potential

ENERGY SUPPLY SCENARIO

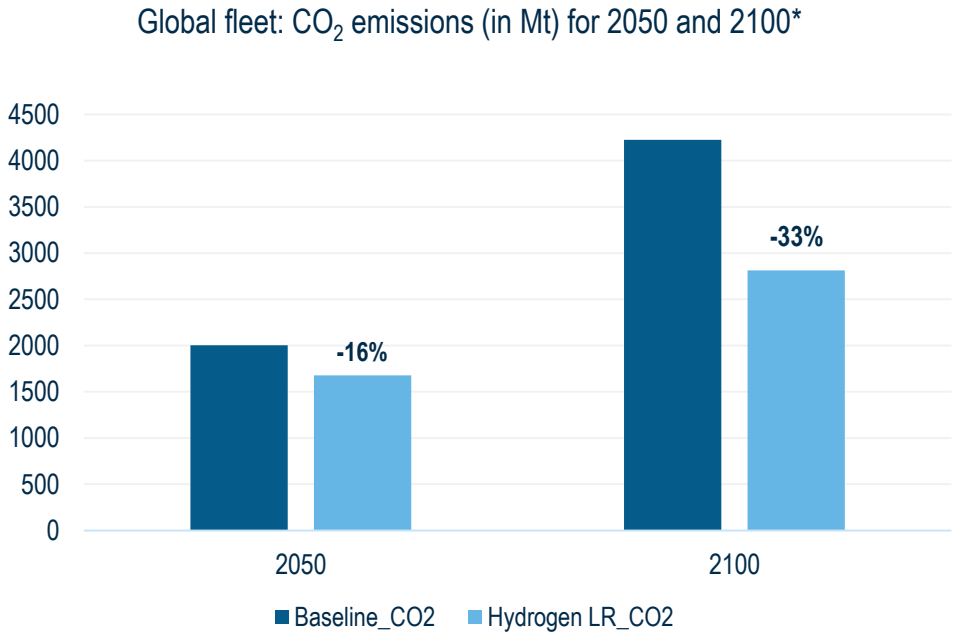
1. LH_2: Reduced cost vs Alternative Fuels
2. Facilitation of synergies between different sectors
3. Scalable, cost-efficient production

BUSINESS MODEL INNOVATION

1. Continuous connecting banks
2. Seat exchange platform
3. On-board services

AIRCRAFT AND CABIN DESIGN

1. Speed vs SFC
2. Passenger comfort vs Speed
3. Synergies LH_2 – Cabin



*Entry into service: 2040+

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